

The Asiatic clam *Corbicula fluminea* (Müller, 1774) (Bivalvia: Corbiculidae) in Europe

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Abstract. Two populations of *Corbicula fluminea* were found in the Iberian Peninsula; one in Spain and the other in Portugal. A detailed description in terms of ecology, shell morphology and microstructure, morphometrics and anatomy is given for the Spanish population from the Miño River. Lectotypes for *Tellina fluminea* and *T. fluminalis*, and a neotype for *T. fluviatilis* are designated and illustrated. Distribution and spread of *C. fluminea* in Europe are revised. Comparisons among some European populations and the populations from Canton, China, and the Miño River are made. Results suggest that, except for one doubtful population, all records of *Corbicula* in Europe are attributable to *C. fluminea*.

Corbicula taxonomy begins in 1774 with Müller who described three species in the genus *Tellina* Linne', 1758: *T. fluminalis* "in fluvio Asiae Euphrat"; *T. fluminea* "in arena fluviali Chinae"; *T. fluviatilis* "in flumine emporium Canton Chinae praeterlabente". Since then, many living species of *Corbicula* Mühlfeldt, 1811, have been described in freshwater and estuarine habitats from Southeast Asia, the Indian subcontinent, the Pacific islands, and the easternmost part of Europe and Africa (McMahon, 1983). The fossil record of *Corbicula* includes Europe, North America and Japan (see Linstow, 1922; Zhadin, 1952; Ellis, 1978; and Britton and Morton, 1979 for a review).

The first published record of *Corbicula* in North America is that of Burch (1944) in 1938. Counts (1981, 1985) cites the presence of the species in 1924 and 1937 in Nanaimo, Vancouver Island, British Columbia, Canada, and in Raymond, Pacific County, Washington, respectively. Since then, it spread widely in most lotic and lentic habitats, being a pest with very important economic and ecological effects (Sinclair and Isom, 1963; McMahon, 1983). Many papers have been published with records of new localities and biological data using different species names, mainly *C. fluminea*, *C. manilensis* and *C. leana* (McMahon, 1983 and references therein). Several hypotheses about the importance of the role of human activities in the spread of *Corbicula* have been treated (e.g. Thompson and Sparks, 1977; McMahon, 1982).

The wide geographical and ecological range of *Corbicula* seems to be related to the great variation in shell form and colour. These two features are the most common taxonomic characters and the only ones used by the early conchologists, suggesting that *Corbicula* taxonomy probably involves more species names than needed.

Thus, Talavera and Faustino (1933) (*In*: Britton and Morton, 1979) placed *Corbicula manilensis* (Philippi, 1844) into synonymy with *C. fluminea*, Morton (1977) considered *C. leana* to be a junior synonym of *C. fluminea*, while *C. fluviatilis* was previously placed into synonymy with *C. fluminea* by Prasad (1929). Moreover, a thorough review by Britton and Morton (1979) lead the authors to consider that most Asiatic species previously described could be attributed to two taxa: the freshwater species *C. fluminea* (Müller, 1774) and the estuarine species *C. fluminalis* (Müller, 1774).

Studying North American populations of *Corbicula* on the basis of ecology, functional morphology and reproductive biology, Britton and Morton (1979) concluded that all belonged to the single species, *C. fluminea*. The results of this paper, and the conclusions of Morton (1982), seem to provide a good discrimination between *C. fluminea* and *C. fluminalis*.

In the last decade, *Corbicula* was also introduced into South America (Ituarte, 1981) and Europe. Mouthon (1981) reports the presence of *C. fluminalis* in France (La Dordogne) and in Portugal (Tajo River estuary). Nagel (1989) cites the species from the Duero River near Oporto (Portugal) and Girardi (1989-1990) indicates the occurrence of *C. fluminalis* also in France at the Canal du Midi at Grisolles (Tarn and Garonne). We found two *Corbicula* populations in the Iberian Peninsula, one in Spain and the other in Portugal, apparently corresponding to *C. fluminea*. These facts suggest that, as occurred in North America, Europe is being currently invaded by this bivalve and that species discrimination is probably not as clear as previously thought (Morton, 1982), because it still seems to allow the use of various species names for morphological variants of the same species concept.

Thus, the Iberian populations are described in detail in relation to shell and anatomical characters in order to clarify the taxonomy and distribution of *Corbicula*. The results are compared with bibliographical data and museums material, including the Müller collection.

MATERIALS AND METHODS

The Miño River was sampled from its source to its mouth. The first samplings were carried out in July and October 1989. From June 1990 to June 1991 a monthly sampling was done at Goian, near Vigo in Galicia, Spain, 13 kms from the sea (Fig. 1) (UTM coordinates 29TNG208436).

The specimens of the Duero River were collected at Regua (Portugal) in the shore by the Karaman-Chappuis method (Motas, 1962). In the Miño River, the clams were collected by snorkeling, dredging the bottom and sieving the mud along the shore.

Temperature, dissolved oxygen, pH and water turbidity were monitored at Goian (Miño River) using an Horiba water checker Model U-7. Conductivity was measured using a Crison conductivimeter Model 523. Values of alkalinity, calcium, total water hardness and carbonate hardness were obtained *in situ* with Merck Aquamerck. No physicochemical data are available from the Duero River.

Some specimens were maintained alive in aquaria at the laboratory for anatomical studies. Prior to the dissections, animals were relaxed with menthol or 1% sodium-pentobarbital (nembutal), extracted from the valves and stained with neutral red.

Shell pores and other microstructural features were observed in the Miño River population with a Jeol JSM T330A scanning electron microscope at accelerating voltages of 15 and 20 kV. Juvenile and adult valves were submerged in 5% sodium hypochlorite (Clorox) for more than 24 hours, cleaned in distilled water with ultrasound, dried at 50°C and then coated (whole or fractured) with a thin layer of gold-palladium in a Balzer SCD 004 Sputter Coating Unit.

Shell phenotypes were described. Then, the specimens were compared with descriptions in the literature and specimens in the collections. In addition to the typical measures (length, width and height), and to describe the variability of *Corbicula* shells, seven measurements shown in figure 2C plus the shell perimeter were determined using a caliper read to the nearest 0.01 mm and *camera lucida* drawings of each left valve. The total shell length (L) was used as a standard size measure for statistical adjustment of the measured variables. The angle (A) inscribed between the inner inflection point of the hinge and the ends of the lateral teeth, and the one between the lines d and d' in figure 2C (Add') were also measured on the *camera lucida* drawings, and transformed in radians for statistical analysis. We also registered the number of sulcations per 5 mm medially measured along the dorsoventral axis and the number of denticles per millimeter in the anterior lateral tooth, both in the left valve. A total of 58 European specimens of *Corbicula* were measured: 45 from the Miño River at Goian (Spain), nine from the Duero River at Regua (Portugal) and four from the Duero (Portugal) (Karl Otto-Nagel, coll.).

The mean, standard error, standard deviation and the coefficients of variation from the Miño River population were calculated to evaluate the least variable characters and therefore the most suitable for taxonomic purposes. The Müller collection material listed in the following section was also measured for comparisons. These were made among Miño, Duero (Regua), Duero (Nagel coll.) and Canton populations.

Corbicula lacks well-defined stages of growth and adult size is highly variable. In addition, sampling biases due to the use of previously collected material from archival collections could cause artificial heterogeneity across samples (Reist, 1985). Thus for morphometrics to be useful for taxonomy they must compensate for allometric relationships and be able to estimate differences in shape by removing confounding effects of absolute shell size. As size and shape covary, an analysis of covariance, with L as the covariate (Packard and Boardman, 1987), was performed on the original data and the among-groups residuals used to describe shape and in subsequent statistical procedures (Reist, 1985, 1986). The residuals of each measurement were then examined by an analysis of variance and Duncan multiple range test to determine significantly different pairs of means.

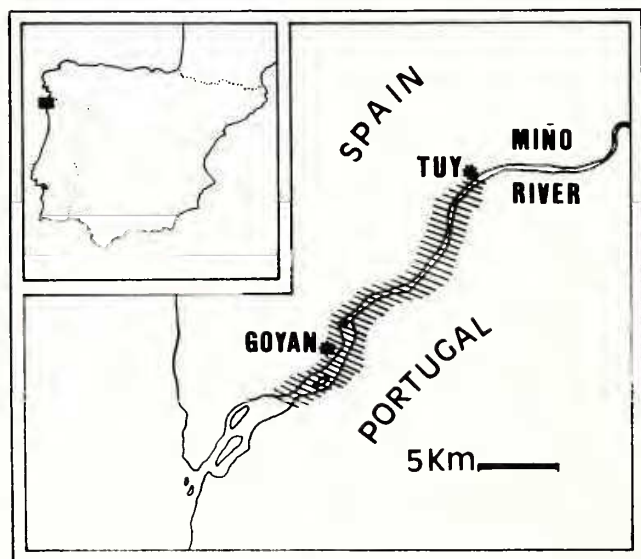


Fig. 1. Map of the distribution of *Corbicula fluminea* in the Miño River.

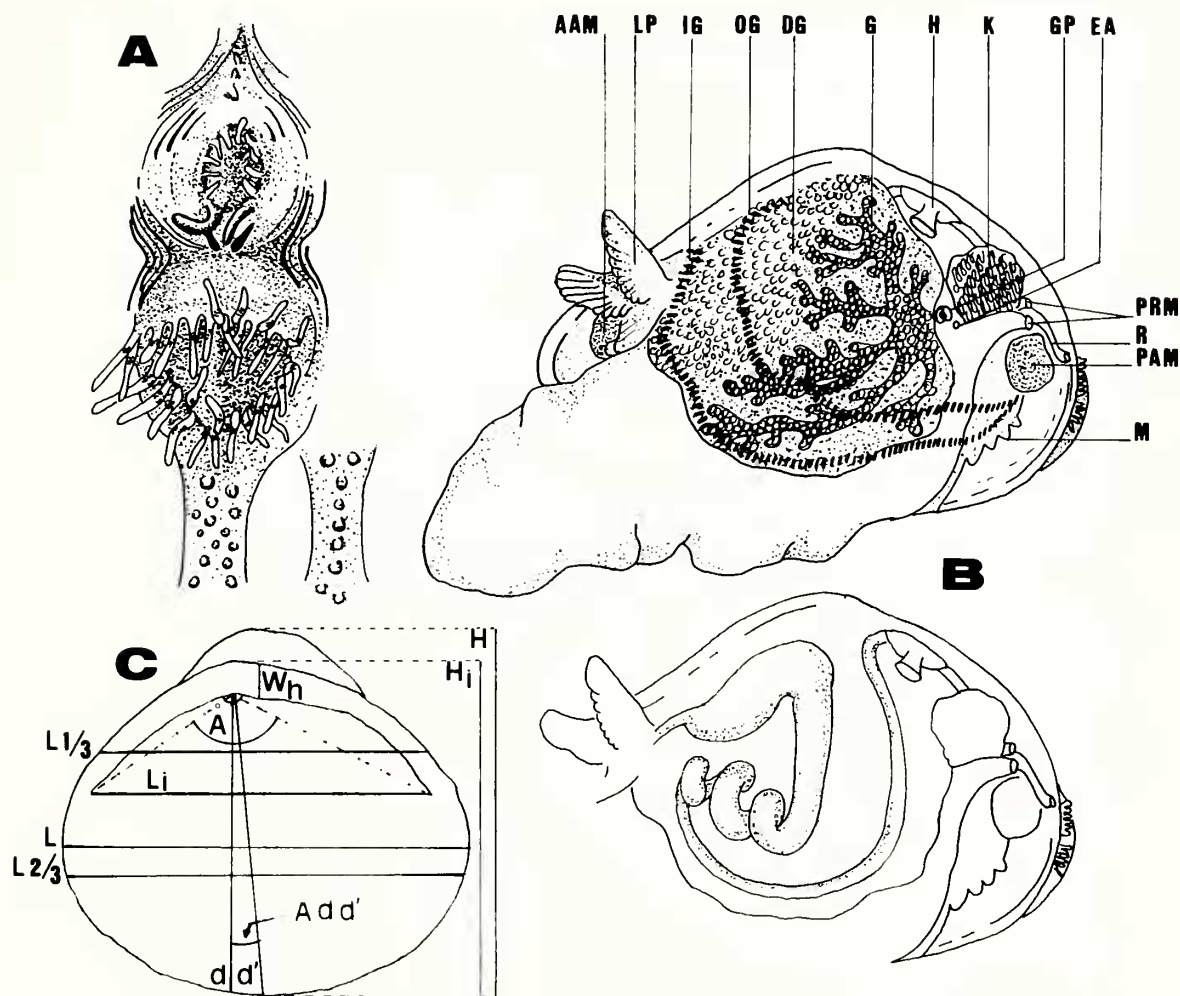


Fig. 2. Spanish *Corbicula fluminea*: **A**, siphons; **B**, anatomy (AAM, anterior adductor muscle; LP, labial palps; IG, inner gill; OG, outer gill; DG, digestive gland; G, gonad; H, heart; K, kidney; GP, gonopore; EA, excretory aperture; PRM, posterior pedal retractor muscle; R, rectum; PAM, posterior adductor muscle, M, mantle). **C**, left valve showing standard measurements (L, length; $L \frac{1}{3}$, length at $\frac{1}{3}$ of height; $L \frac{2}{3}$, the same at $\frac{2}{3}$; L_i , length between the ends of the lateral teeth; H, height of the shell; H_i , distance between the upper border of the hinge and the lower end of the shell; W, width of the complete shell; W_h , width of the hinge; P, perimeter of the valve; d, distance between the angle down the anterior cardinal tooth and the lower end of the valve, perpendicular to L_i ; d' , bisector of the mentioned angle; A, angle; Add, angle between d and d' .

TYPE MATERIAL

Concerning the three species of *Corbicula* described by Müller (1774), it was impossible for us to find any properly designated type material. Counts (1991) says that the holotypes of *Corbicula fluminea*, *C. fluminalis* and *C. fluviatilis* are in the Universitetets Zoologisk Museum of Copenhagen (UZMC), and Morton (1977) and Britton and Morton (1979) illustrate three of these specimens as the types of the three species. However, no data about the origin of the supposed type specimens of *C. fluminea* and *C. fluviatilis* are available at the Zoologiske Museum (T. Schjøtte, pers. comm.). On the other hand, it was impossible to obtain specimen #152926 of *C. fluminea* in the Museum of Com-

parative Zoology at Harvard cited as the paratype by Counts (1991) and quoted by Johnson (1959) as cotype. Therefore, in this paper we designate lectotypes for *Tellina fluminea* and *T. fluminalis* and a neotype for *T. fluviatilis* as follows.

***Tellina fluminea*.** There is no type designated properly. We have studied the following material from the UZMC: two whole shells and two valves from an unknown locality in Müller's collection; three whole shells and two valves from Canton, China, unknown collection; 15 whole shells from Canton, China in Spengler's collection; one whole shell from Canton, China. Probably in Müller's collection (T. Schjøtte, pers. comm.). This specimen was quoted and figured without label data by Kennard and Woodward (1926) as the "cotype" (meaning syntype). It is designed here as the lectotype; one

whole shell from East India or China in Müller's collection. It was quoted and figured by Prashad (1929) who stated that it could be accepted as the "cotype" of the species. This specimen was figured by Morton (1977) and Britton and Morton (1979) and taken to be the type. It is not recognized here as a syntype because of the doubtful locality and because its measurements do not fit the original description. **Lectotype** (Fig. 3): The specimen (14.9 x 13.7 x 10.2 mm) from Canton, China, and probably in Müller's collection (UZMC) agrees with the original description and measurements (Müller, 1774).

Tellina fluminalis. The mention of a "cotype" from Müller's collection by Kennard and Woodward (1926) is not a valid lectotype designation. We consider that the mention of "type" by Britton and Morton (1979: Fig. 3) is a valid designation of lectotype according to the Article 74 a of the ICZN. **Lectotype**: (Fig. 3). One specimen (29.9 x 30 x 21.8 mm) from the Euphrates River, Mesopotamy, in Müller's collection (UZMC) agrees with the original description, measurements and locality (Müller, 1774).

Tellina fluviatilis. Kennard and Woodward's (1926) plesiotypes have no nomenclatural value, not coming from Müller's specimens. Prashad (1929) recorded one specimen as the topotype. This is not a valid designation. The specimen figured by Morton (1977) and Britton and Morton (1979) is from Spengler's collection. The sole specimen of this species in Müller's collection is from Tranquebar, India, therefore we designate here the specimen from Canton, China, figured by Morton (1977) and Britton and Morton (1979) as the neotype of the species. **Neotype**: One specimen (19.6 x 17 x 10.6 mm) from Canton, China, in Spengler's collection (UZMC) agrees with the original description and locality. The specimen is equivalve, near equilateral and integropaleate, with an external sculpture of concentric sulcations. There are eight sulcations in 5 mm of the medial region of the left valve. The colour of the periostracum is dark brown with a pale medial concentric band. The umbones are eroded and white. Internally it is violet, darker near the edge and in the area of the siphons. Lateral teeth are white with eight denticles per millimeter measured in the medial region of the anterior lateral tooth of the left valve (Fig. 3). The left valve shows the manuscript letters "Sp".

RESULTS

ECOLOGY

No *Corbicula* were observed in the samples collected in July 1989. Nine juvenile specimens were found in October 1989, and in June 1990 a large number of adults and juveniles were found. Several samplings since then show that the number of *Corbicula* and the area occupied are increasing. In January 1991 the species reached from 8 to 24 km upstream

(Fig. 1). The population found at Regua (Portugal) in April 1989 indicates that the species also invaded the Duero River where it lives buried into the gravel in the margins of the river.

In the Miño River, *Corbicula* lives in a section of river 400 m wide that is under tidal influences. Water temperature ranges from 9.2°C in January to 27°C in July. Accordingly, registered values of pH are from 5.9 to 8.2. Values of conductivity at 25°C are low as expected from freshwater habitats in granitic areas. Minimum value is 54 μ S which correspond to January. It increases during the summer reaching to 450 μ S in September. These values are clearly associated with those of total hardness (1 - 3.8 °dH) for the same months. Less variation was found for carbonate hardness (1 - 1.8 °dH). Calcium varies from 7 to 18 mg/l and alkalinity from 0.4 to 0.8 mmol/l. Higher values of both parameters were also registered in summer. These yearly variations seem to be related with changes in the marine influence and the water river contribution. The Miño River has well oxygenated waters as shown by the observed values of dissolved oxygen, between 7.8 and 12.4 ppm.

Specimens in the shore were sampled at a depth up to 8 cm, which means that at low tide *Corbicula* lives some hours out of the water. Many more specimens were observed living in the middle of the river (about 6 m depth) in gravel and sandy substrata, than in the sand and mud of the shore. They are also frequent in the mud retained by the vegetation. Flora of the area includes many *Elodea canadensis* Michx., an invasive species, *Potamogeton* sp., *Ranunculus* sp. and *Ceratophyllum* sp.

Other molluscs living in the area are: *Musculium lacustre* (Müller, 1774); *Pisidium amnicum* (Müller, 1774); *P. henslowianum* (Sheppard, 1823); *Potomida littoralis* (Cuvier, 1797); *Unio pictorum* (Linné, 1758); *Anodonta cygnea* (Linné, 1758); *Gyraulus* sp.; *Bithynia tentaculata* (Linné, 1758); *Potamopyrgus jenkinsi* (Smith, 1889); *Valvata piscinalis* (Müller, 1774); *Lymnaea* sp.; *Hippeutis complanatus* (Linné, 1758); *Physa acuta* Draparnaud, 1805 and *Ancylus* sp. The abundance of *Bithynia tentaculata* was spectacular. It is also important to mention that *Pisidium amnicum* was one of the dominant molluscan species in the samples prior to September 1990. In this month only a few specimens were found and since then the population has become extinct. This was coincident with the appearance of a pest of the Cyanophyta *Microcystis aeruginosa* (Kütz). However, in spite of the fact that the algal bloom receded, in the following month no living specimens of *P. amnicum* could be found. In the most downstream locality for *Corbicula* the only accompanying species was *P. jenkinsi* whose abundance is considerable.

SHELL MORPHOLOGY AND MICROSTRUCTURE

The shell of European *Corbicula* is equivalve, near

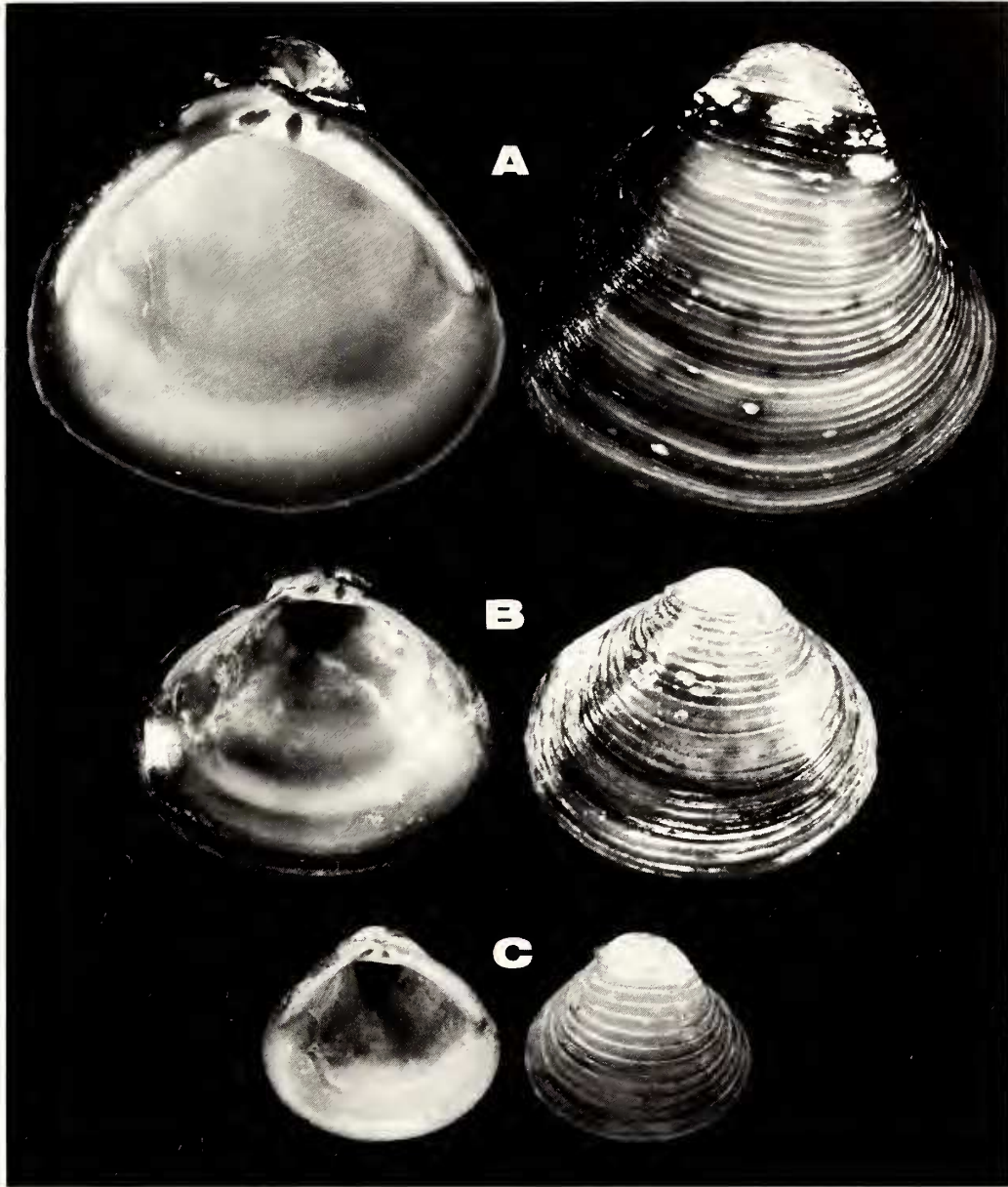


Fig. 3. A. Lectotype of *Corbicula fluminalis*; Euphrates River, Mesopotamy; U.Z.M.C. (29.9 x 30 x 21.8 mm). B. Neotype of *C. fluvialilis*; Canton, China; U.Z.M.C. (19.6 x 17 x 10.6 mm). C. Lectotype of *C. fluminea*; Canton, China; U.Z.M.C. (14.9 x 13.7 x 10.2 mm).

equilateral, integropaleate, thick and heavy. The shape is oval in juveniles and tends to be near triangular in adult specimens. The surface has well marked concentric and regular sulcations. The number of sulcations in 5 mm of shell appears to be independent of age and varies between four and eight, specimens with five or six sulcations being most frequent (Table 1, Fig. 4A). The hinge is typically heterodont with three cardinal teeth on each valve, and two crenulate lateral teeth, simple in the left valve and double in the right one. In the Miño River population the number of denticles per

mm of cardinal tooth is also independent of age. It varies from five to eight, six denticles specimens being most frequent (Table, 1, Fig. 4B). The ligament is exterior and prominent (Fig. 5).

The periostracum is yellow-brown in all the specimens. The inner surface of the shell is white with a more or less violet dye (Fig. 5).

In the Miño River juveniles, it is frequent to see three strongly pigmented violet areas, one central and triangular and two lateral, just below the lateral teeth, that are also ex-

Table 1. Descriptive statistics of the Miño River population (Note: Var., variable acronym as in Fig. 2, except N°S/5mm=number of sulcations in 5 mm, and N°D/mm=number of denticles per millimeter of anterior lateral tooth; SD, standard deviation; SE, standard error; Min., minimum; Max., maximum; CV, coefficient of variation; N=45).

Var.	Mean	SD	SE	Min.	Max.	CV
L	15.82	2.66	0.39	9.7	20.0	16.81
L 1/3	14.11	2.15	0.32	8.9	16.9	15.25
L 2/3	15.26	2.63	0.39	9.3	19.5	17.21
Li	12.97	2.12	0.32	8.5	16.2	16.34
H	13.35	2.29	0.34	8.4	17.2	17.16
Hi	12.12	2.00	0.29	7.6	15.4	16.53
W	9.49	1.49	0.22	6.3	11.9	15.72
Wh	0.85	0.19	0.03	0.4	1.4	22.91
P	45.94	7.61	1.13	28.5	58.0	16.56
d	11.08	1.83	0.27	7	14.3	16.48
d'	11.23	1.83	0.27	7.1	14.3	16.27
N°S/5mm	5.44	0.96	0.14	4	8	17.75
N°D/mm	6.15	0.71	0.10	5	8	11.46
A	2.21	0.07	0.01	2.02	2.48	3.31
Add'	0.27	0.04	0.006	0.16	0.34	16.81

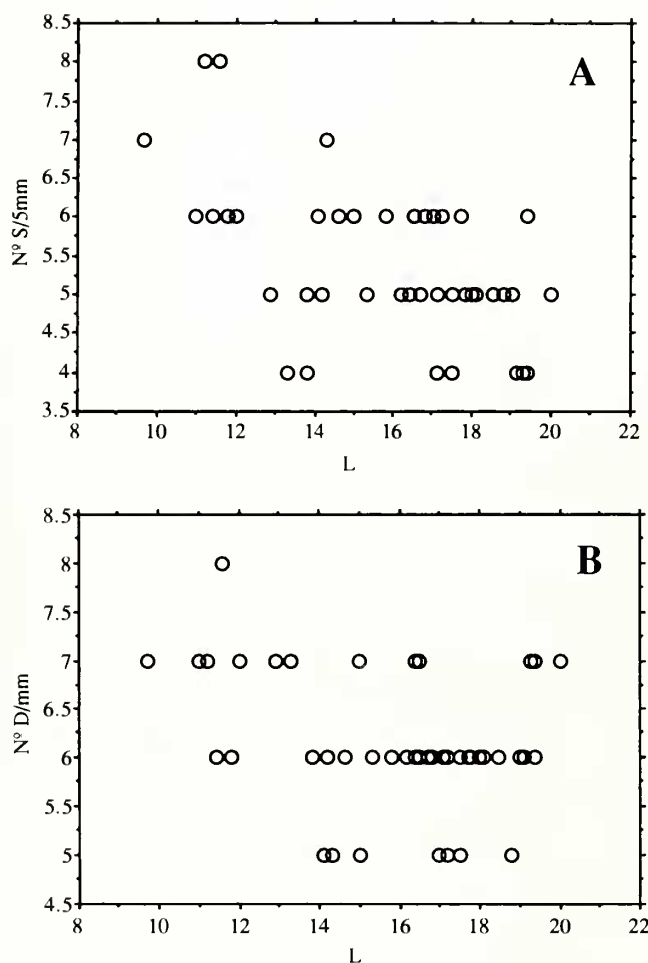


Fig. 4. *Corbicula fluminea* from the Miño River. Variation with length in the A. Number of sulcations per 5 mm, and B. Number of denticles per mm of the anterior lateral tooth.

ternally visible. The central one usually spreads and stumps in adults, with variable pigment intensity among specimens. The lateral areas surround two clear yellowish zones at both sides of the umbo, corresponding to the lunula and the scutcheon which are more marked in dark specimens (Fig. 5). In the Duero River population, the violet color is more faint, the umbones are eroded and the dark lateral bands are nearly absent (Fig. 5).

In scanning micrographs of juvenile shells from the Miño River (2 - 3 mm in length) treated with sodium hypochlorite, the prodissoconch (Fig. 6A) is smooth with irregular granules in a random pattern (Fig. 6B) lacking pores and striation. Sulcations in the early dissoconch are crossed by thin radial ribs in a more or less regular disposition, thus forming a reticulate microsculpture. Downwards, the ribs disappear and they are substituted by a concentric zone with a peculiar design in which parallel and narrow sulcations are grouped forming irregular bands radially disposed (Fig. 6C). No microsculpture is observed in the later dissoconch.

Shell pores are present in both surfaces of the dissoconch being more abundant in the inner surface of the early dissoconch, where the estimated density reaches about 200 pores per square millimeter in specimens between 2 and 3 mm in length (Fig. 6D). Pores are circular in cross-section and their diameter is about 2 μ m at the outer surface (Fig. 6F) and 2.5 μ m at the inner one, where they are funnel-shaped (Fig. 6E, G, H, I). The pores are openings of narrow tubules that cross perpendicularly the shell (Fig. 6G), although most of them are blinded just before reaching the outer shell surface (Fig. 6H). Some of these tubules seem to be filled although the nature of the filling material is uncertain at present (Fig. 6J).

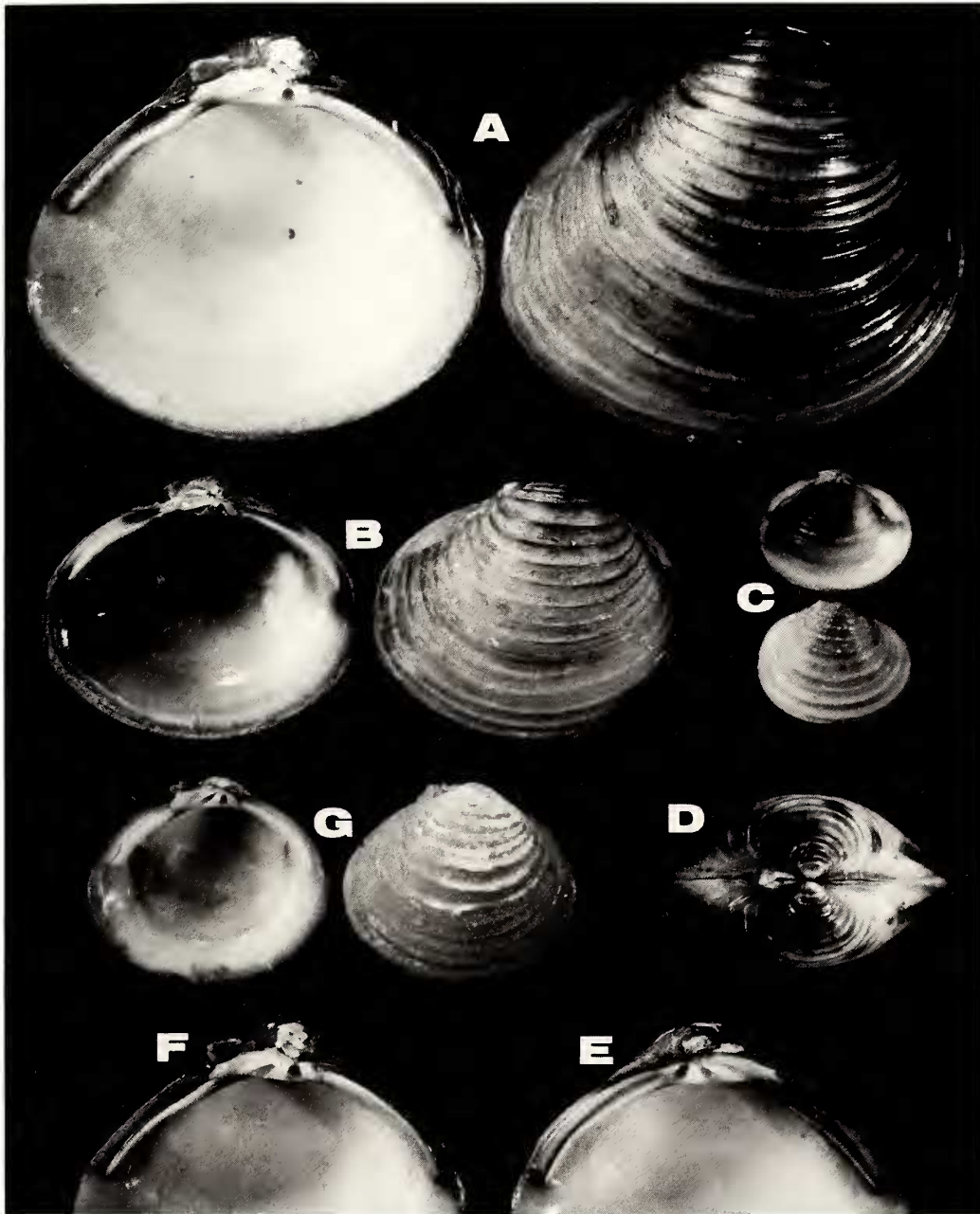


Fig. 5. *Corbicula fluminea* from Iberian Peninsula. A, B, C. Three different sizes from the Miño River (A=24.5 mm; B=17.2 mm; C=8 mm). D. Umbo of a specimen from the Miño River. F, E. Hinge and umbo of A. G. Specimen from the Douro River (13 mm).

SHELL MORPHOMETRY

Descriptive statistics for the Miño River population are given in Table 1. Variation about the means is substantial, the coefficients of variation being about 17%, except for the width of the hinge that seems to be very variable (23%), the number of teeth (11.5%) and the angle A (3.3%) which is the least variable measurement.

A similar situation is found for the raw, pooled data (Table 2). This table also shows that all variables are significantly positively correlated with L ($p < 0.0001$ except $p < 0.03$ for the A angle), suggesting that size has an important effect on shape. Most of the relationships are linear or nearly so ($r > 0.90$) and the variables roughly isometric with the standard size measure for the size range considered

Table 2. Parameters of the untransformed pooled data set for the following populations: Miño, Duero (Regua), Duero (Nagel sample), Canton (China) (Note: Var., variable acronym as in Fig. 2D; SD, standard deviation; SE, standard error; Min., minimum; Max., maximum; CV, coefficient of variation; b, slope; a, intercept; r, correlation coefficient; *, $p < 0.0001$; **, $p < 0.03$; $n=73$).

Var.	Sample statistics						Regression statistics					
							Variable on L			Log on Log. L		
	Mean	SD	SE	Min.	Max.	CV	b	a	r	b	a	r
L 1/3	13.71	3.03	0.35	6.6	21.1	22.07	0.777	1.56	0.98*	0.918	0.04	0.99
L 2/3	15.12	3.82	0.44	7.1	27.2	25.32	0.995	-0.43	0.99*	1.025	-0.04	0.99
Li	12.84	3.19	0.37	6.0	22.5	24.86	0.827	-0.08	0.99*	1.004	-0.09	0.99
H	13.51	3.50	0.40	6.4	25.0	25.90	0.896	-0.49	0.98*	1.013	-0.08	0.98
Hi	12.36	3.15	0.36	6.0	22.7	25.50	0.802	-0.18	0.98*	0.983	-0.08	0.98
W	9.50	2.48	0.29	4.1	18.2	26.18	0.628	-0.31	0.97*	1.033	-0.25	0.97
Wh	0.96	0.36	0.04	0.4	25.0	37.16	0.076	-0.22	0.81*	1.00	-1.22	0.79
P	45.65	11.26	1.31	21.0	80.0	24.66	2.920	0.01	0.99*	1.00	0.46	0.99
d	11.19	2.84	0.33	5.4	20.7	25.42	0.730	-0.22	0.98*	0.996	-0.14	0.98
d'	11.36	2.87	0.33	5.5	21.0	25.27	0.735	-0.13	0.98*	0.990	-0.12	0.98
A	2.12	0.13	0.01	1.8	2.5	6.30	-0.008	2.26	0.25**	-0.045	0.38	0.18
Add'	0.26	0.06	0.007	0.12	0.46	24.60	0.017	0	1*	1	-1.76	1
L	15.63	3.84	0.45	7.5	27.3	24.60	---	---	---	---	---	---

(slope of log-log regression was about 1.0).

The high correlation of all variables with L indicate that a univariate approach is reasonable for size adjustment, with L as a standard size variable for it. None of these tests were significant which indicates that there are no measurements that could separate any of the four populations studied.

ANATOMY

The siphons of the Miño River *Corbicula* (Fig. 2A) are of ambarine-orange color with black spots and areas. The two siphons are internally surrounded by a black ring. Between the two siphons, and from the exhalant one, there are two well marked black lines. The siphons are surrounded by tentacles, usually with pigmented bases. Those of the inhalant siphon are longer and with black spots in the middle. There is no rule in the disposition of the fused mantle folds papillae down to the inhalant siphon. There are specimens with a single row and others with the papillae in a random pattern (Fig. 2A) and intermediate situations may be observed.

The gonadal tissue occupies, in the reproductive season, most of the visceral mass. Each gonad is formed by greenish arborescent follicles branching through the stroma of the visceral mass. The common branch leads to a single gonopore, one on each side of the body just above the excretory aperture in the latero-dorsal edge of the visceral mass (Fig. 2B).

One specimen of Goian, captured in July 1990, presented developing larvae in the inner demibranchs (Fig. 7). The larvae are bivalved and D-shaped.

DISCUSSION

All the European localities described for *Corbicula*

demonstrate the species lives in substrata of sand, mud and gravel. The habitats are lotic areas receiving tidal influences with the exception of the French population cited by Girardi (1989-1990).

Physicochemical data of La Dordogne population (Mouthon, 1981) at 21°C are within the range observed in the Miño River. Conductivity values correspond in both cases to freshwaters agreeing with the habitat preferences of *Corbicula flumina* given by Morton (1982) to distinguish this species from *C. fluminalis*. The Tajo estuary population differs from the others in that the salinity varies between 4 and 18‰ (=7.400-30.000 µS) (Mouthon, 1981), which indicates values of salinity much higher than expected for *C. fluminea* (Morton, 1982). No data are available for the populations of the Duero River (Nagel, 1989) or the Canal du Midi (Girardi, 1989-1990).

Shell morphology of the Miño River specimens is similar to that of *Corbicula fluminea* from the UZMC collection and differs from the *C. fluminalis* lectotype (here designated) in that the last is darker, taller and more triangular than *C. fluminea*.

Shell size seems to be the most important difference among the European *Corbicula* populations. Table 3 shows maximum and minimum values of shell length for all the

Table 3. Minimum and Maximum values of shell length in European *Corbicula* populations.

Locality	Min.	Max.	Reference
Tajo Estuary	25	41	Mouthon, 1981
La Dordogne	16	20	Mouthon, 1981
Duero River	18.1	27.3	Nagel, 1989
Duero River (Regua)	7.5	13	This study
Miño River	9.7	20	This study

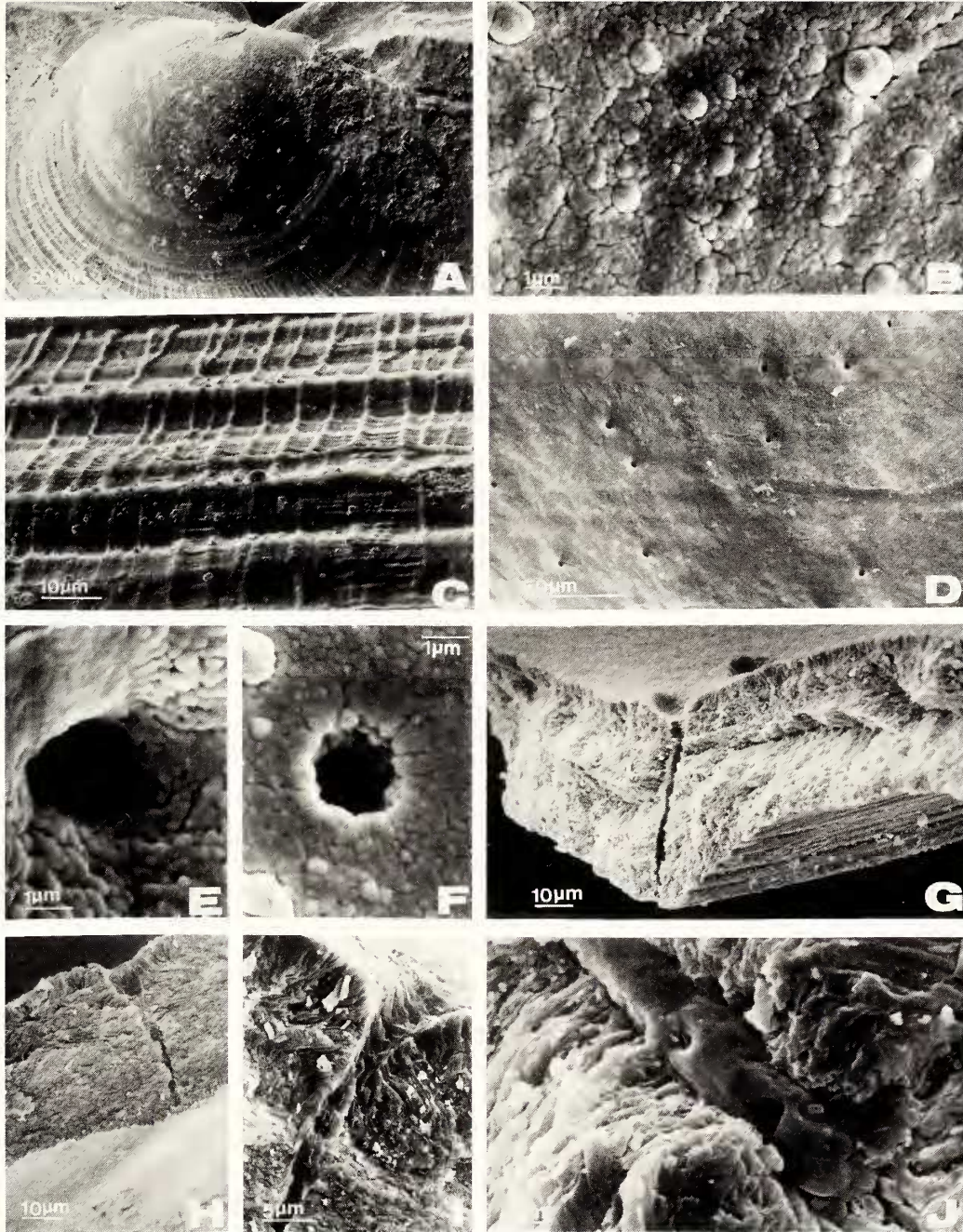


Fig. 6. *Corbicula fluminea* from Miño River. **A.** Prodissoconch. **B.** Microsculpture of the prodissoconch. **C.** Microsculpture of the early dissoconch. **D.** Pores of the inner surface. **E.** Internal pore. **F.** External pore. **G, H, I.** Sections of the shell, showing the pores and tubules. The inner surface above. **J.** Tubule filled with unknown material.

populations. The larger specimens are those of the Tajo Estuary where the smallest shells are greater than the largest ones of other three populations. However, as Britton and Morton (1979) pointed out, “the *Corbicula* shell, in general, lacks good taxonomic markers for species discrimination”, so that according to these authors “giving an excessive value to deter-

minate conchological characters, it has lead up in the current taxonomic confusion”. The results suggest that size has an important effort on shape. For that reason, when shell shape of three populations (Miño River, Duero River at Regua and Duero River- Nagel coll.) and that of Canton, China, is compared after removing the effect of size on the



Fig. 7. Gill of Spanish *Corbicula fluminea* showing the incubated larvae (Length of the larvae = 0.2 mm).

measurements, there are no significant differences among the European populations nor among them and the one from Canton, suggesting that all of them belong to the same species: *C. fluminea*. Unfortunately we have not enough information about the Tajo population to test whether it also belongs to the same taxonomic unit.

Mouthon (1981) cites the presence of many pores in the shell of juvenile specimens of La Dordogne. A detailed microstructural study of *Corbicula fluminea* from the Mississippi River show the existence of 196 pores per square millimeter (Tan Tiu and Prezant, 1989), which is very close to the density found in the Miño River population (200 pores per square millimeter). In scanning electron micrographs of both American and Spanish shells, it is possible to observe that pores are the openings of tubules (Fig. 6G, H), some of them filled by a material identified by the above-mentioned authors as mantle extensions. We have observed similar filling structures in broken shells (Fig. 6J) but the fact that these shells were cleaned with sodium hypochlorite suggest that more studies are needed to determine the composition of the filling material and therefore the function of the tubules.

Concerning the soft parts, Britton and Morton (1979) draw the siphons and describe the differences between *Corbicula fluminea* and *C. fluminalis*. The first often has a band of pigment in the tentacles of the inhalant siphon that is absent in the last. In the exhalant siphon, *C. fluminea* shows a ring of pigment internally and is densely pigmented externally. There are more and bigger sensory tentacles around the exhalant siphon in *C. fluminalis*. The papillae of the fused

mantle folds, dorsal and ventral to the siphons, form a single alternating row in *C. fluminea* and there are many more papillae arranged in a series of rows in *C. fluminalis*.

The *Corbicula* of La Dordogne has small brown spots in the base of the papillae of the two siphons and fine dark bands surrounding the mantle portion near and into the holes of the siphons (Mouthon, 1981). This pigmentation is completely absent in the Tajo River *Corbicula* (Mouthon, 1981) and is very similar to that found in the Miño specimens.

The results of this paper suggest that the number and disposition of the mantle papillae is not a useful discriminating character. The Miño River population has a very high variability including all intermediate situations (Fig. 2A). In the rest of the features they are very close to that described for *Corbicula fluminea* by Britton and Morton (1979).

Finally, Britton and Morton (1979) discriminate *Corbicula fluminea* from *C. fluminalis* by the fact that the former nourished the fertilized eggs within the inner demibranch while they are not retained in the last. Undoubtedly, this represents the most important biological difference between both species, though it is difficult to test in many samples and impossible in conchological museum collections. Figure 7 shows one specimen of the Spanish *Corbicula* population from the Miño River incubating larvae in its inner gill demibranch. This evidence, in addition to the previously discussed data of ecology, shell morphology and anatomical features, confirm the hypothesis that the Miño River population belongs to *C. fluminea*.

The available information on the other European *Corbicula* suggest that there are not enough divergences among them and *C. fluminea* populations to believe that we are dealing with a different species (except for the Tajo Estuary population). This hypothesis is also supported by the large invasive historical record of *C. fluminea* (McMahon, 1982, 1983 and references), not shared by any other *Corbicula* species and the wide ecological range both in natural habitats as in colonized ones.

Regarding ecological effects on the native fauna, the disappearance of *Pisidium amnicum* at Goian was coincident with the *Microcystis aeruginosa* bloom and also with the demographic increase of *Corbicula fluminea*. For this reason it is impossible to assess if only one of these phenomena or both were responsible for this extinction.

Further research about population dynamics and reproductive strategy must be conducted in order to elucidate the growth and invasive speed of *Corbicula fluminea* in Europe, but it is a fact that we are witnessing an introduction of this invasive bivalve in the continent.

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